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- (54) **SIGNAL COMPARISON CIRCUIT**
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(58) **Field of Classification Search** ..... **327/72, 327/77**

(57) **ABSTRACT**

See application file for complete search history.

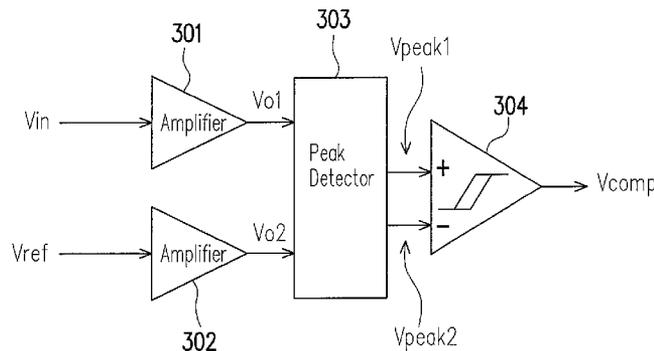
A signal comparison circuit is provided. The signal comparison circuit includes a first amplifier, a second amplifier, a peak detector, and a comparator. The first amplifier is a zero-peaking amplifier. The first amplifier receives and amplifies a data signal. The second amplifier receives and amplifies a reference voltage. The peak detector is coupled to the first and the second amplifiers for detecting and maintaining maximum values of the amplified data signal and the amplified reference voltage, and then outputting the maintained data signal and the maintained reference voltage. The comparator is coupled to the peak detector for comparing the maintained data signal with the maintained reference voltage and outputting a result of the comparison.

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**13 Claims, 5 Drawing Sheets**



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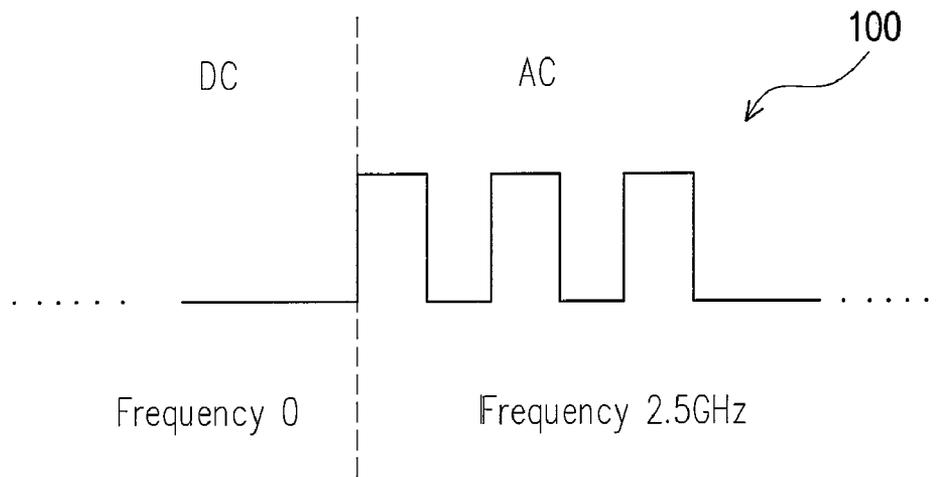


FIG. 1 (PRIOR ART)

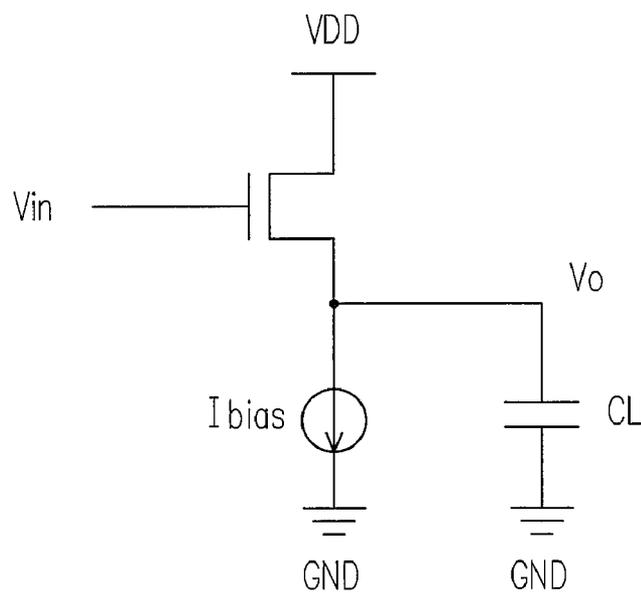


FIG. 2 (PRIOR ART)

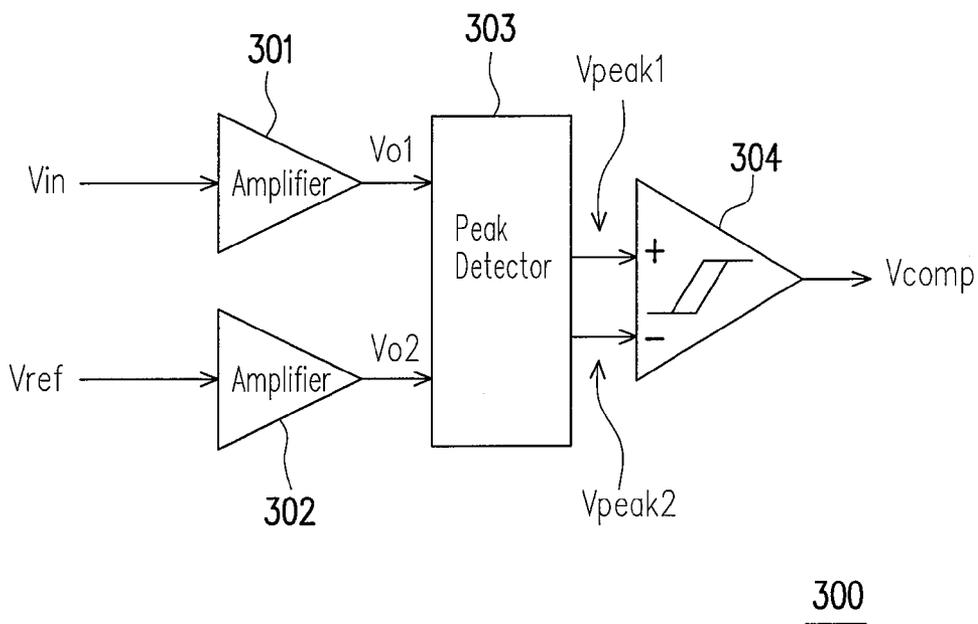


FIG. 3

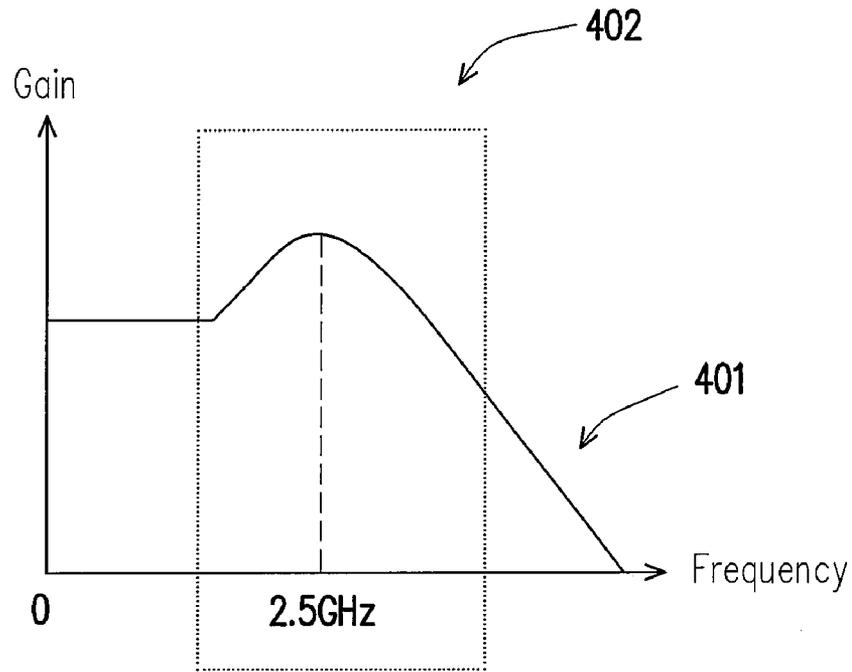


FIG. 4A

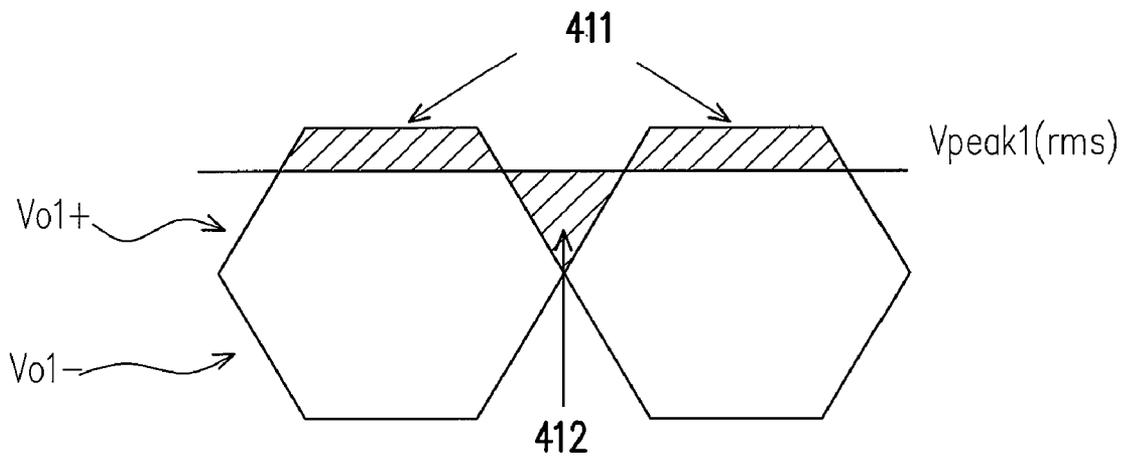


FIG. 4B



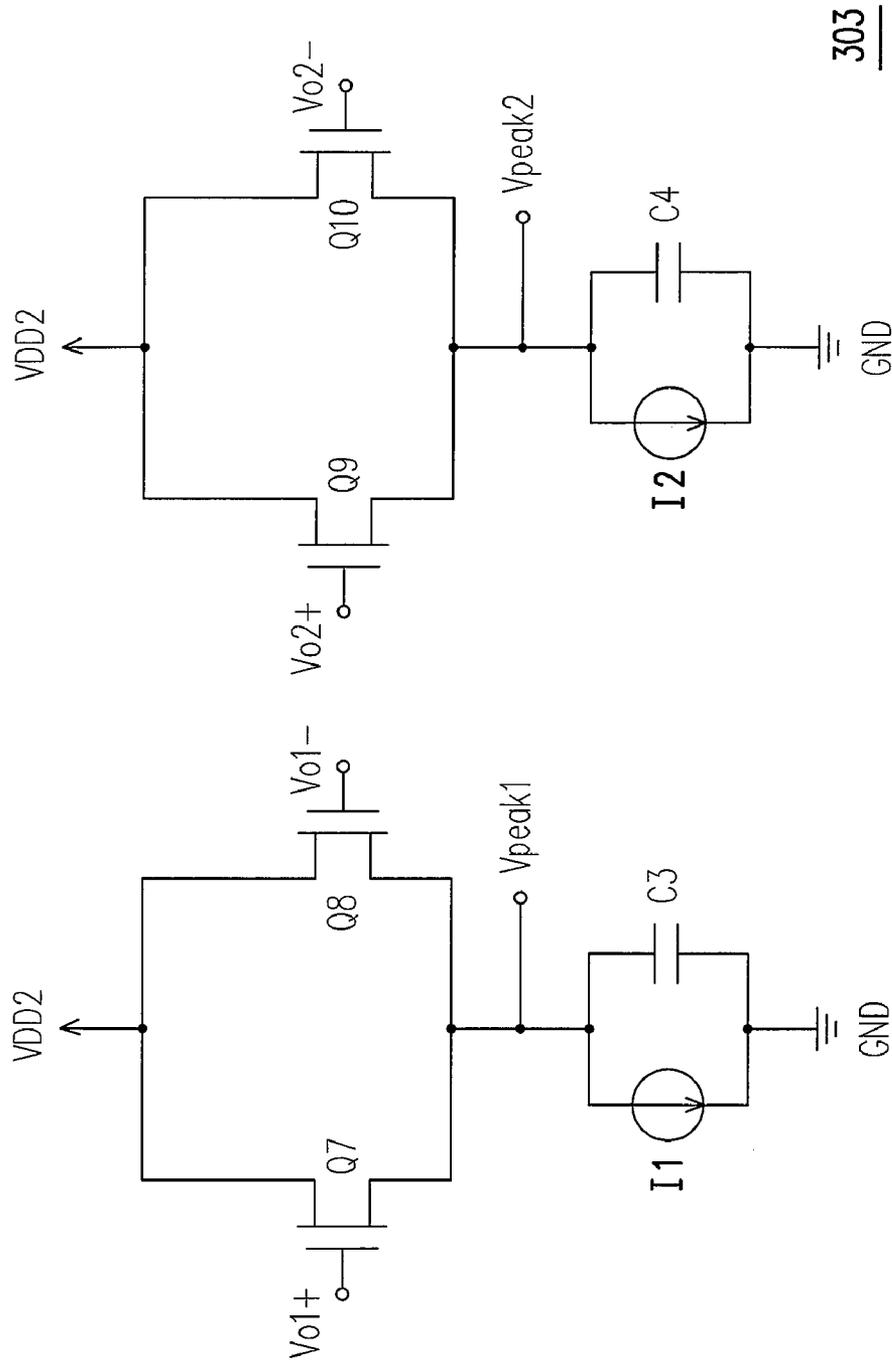


FIG. 6

## SIGNAL COMPARISON CIRCUIT

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

The present invention generally relates to a signal comparison circuit, and particularly, to a comparison circuit for not-return-to-zero (NRZ) data signal.

## 2. Description of Related Art

A comparator is often employed by a high speed serial system for detecting amplitude of inputted signals. The comparator compares the data signals with a predetermined threshold or a reference voltage, wherein signals which are too small are identified as of poor quality and are neglected, and only those qualified by the comparator selection can be received.

FIG. 1 describes a typical NRZ data signal **100**. The signal **100** has two statuses, logic 1 and logic 0. When the status remains unchanged, the data transmitted thereby is logic 0, which is shown in the direct current (DC) part in FIG. 1. When the status changes, the data transmitted thereby is logic 1, which is shown in the Alternating current (AC) part.

Such a high speed serial system is featured as being capable of changing status with an extreme high frequency. As shown in FIG. 1, when a signal **100** is a direct current signal, it has a frequency of 0 Hz, and when the signal **100** is an alternating current signal, it has a frequency of 2.5 GHz. A conventional comparator if employed thereby cannot immediately enhance the operation frequency from 0 to 2.5 GHz, and is incapable of sustain the high speed operation at 2.5 GHz.

In order to solve the aforementioned problem, some other conventional comparators increase frequency bandwidth by increasing current with a current comparing method. However, this method often causes misjudgement when the data signals are changed between logic 1 and logic 0.

Another proposed solution is employing a peak detector in front of the comparator for detecting and sustaining a maximum value of the data signals. A typical peak detector includes a circuit as shown in FIG. 2, wherein  $V_{in}$  represents an input signal, and  $V_o$  represents an output signal. After passing through the peak detector, the data signal declines to a low frequency signal, which can be conveniently processed by the conventional comparators.

Unfortunately, the peak detector requires a current leakage path for discharging charges from a peak detecting capacitor, and only after the charges are discharged, amplitudes of next input data can be compared. When the alternating current data signal changes status, an output voltage of the peak detector will decrease due to the discharging system, thus causing misjudgement.

In summary, conventional comparators have limited operable frequency bandwidth. However, current mode comparators are likely to cause misjudgements when changing status. Further, if employing a peak detector, there raises a problem of voltage droop when comparing alternating current signals. It becomes a major concern to provide an ideal solution.

## SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to a signal comparison circuit for solve the above-mentioned problem, i.e., misjudgement related to current mode comparator and voltage droop caused by peak detector.

The present invention further provides signal comparison circuit. The signal comparison circuit includes a first amplifier, a second amplifier, a peak detector, and a comparator. The first amplifier is a zero-peaking amplifier, adapted for

receiving and amplifying a data signal. The second amplifier receives and amplifies a reference voltage. The peak detector is coupled to the first amplifier and the second amplifier. The peak detector is adapted for detecting and maintaining a maximum value of the amplified data signal and the reference voltage. The comparator is coupled to the peak detector for comparing the maintained data signal and the reference voltage, and outputting a comparison result. The comparator features in delaying comparison.

In an embodiment according to the present invention, the peak detector includes a capacitor for maintaining the maximum value of the amplified data signal and the reference voltage, and a full wave rectifier structure which is functional to both of a positive semi-cycle and a negative semi-cycle of a differential signal.

Comparing with the conventional, the present invention does not employ the current mode comparator, and therefore does not cause any misjudgement when changing status of the data signal. The zero-peaking amplifier generates relatively large gain for alternating current data signals for compensating voltage droop caused by the peak detector. The peak detector according to the present invention is designed with a full wave rectifier, so as to be capable of comparing both of the positive semi-cycle and the negative semi-cycle of the differential signal. According to the present invention, a path of a direct current data signal and a path of the reference voltage are completely symmetrical configured. As such, the present invention is accurate in comparing direct current data signals. In another hand, the present invention would not cause misjudgement when comparing alternating current data signals.

## BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

FIG. 1 is a schematic diagram illustrating a conventional not-return-to-zero (NRZ) data signal.

FIG. 2 is a part of a circuit diagram of a conventional peak detector.

FIG. 3 illustrates a signal comparison circuit according to an embodiment of the present invention.

FIG. 4A is a gain curve of a zero-peaking amplifier of the signal comparison circuit as shown in FIG. 3.

FIG. 4B illustrates an output voltage of the peak detector of FIG. 3.

FIG. 5 is an amplifier circuit diagram of FIG. 3.

FIG. 6 is peak detector circuit diagram of FIG. 3.

## DESCRIPTION OF THE EMBODIMENTS

Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

FIG. 3 illustrates a signal comparison circuit **300** according to an embodiment of the present invention. The signal comparison circuit **300** is adapted for detecting a quality of an NRZ data signal  $V_{in}$ . The signal comparison circuit **300** includes amplifiers **301**, **302**, a peak detector **303**, and comparator **304**. The amplifier **301** receives and amplifies the NRZ data signal  $V_{in}$ . The amplifier **302** receives and amplifies a reference voltage  $V_{ref}$ . The peak detector **303** is coupled

to the amplifiers **301** and **302** for detecting and maintaining maximum values of amplified data signal  $V_{o1}$  and amplified reference voltage  $V_{o2}$ , and thereafter outputting the maintained data signal  $V_{peak1}$  and the maintained reference voltage  $V_{peak2}$ . The comparator **304** is coupled to the peak detector **303**, for comparing the maintained data signal  $V_{peak1}$  with the maintained reference voltage  $V_{peak2}$ , and outputting a comparison result  $V_{comp}$  as a quality index of the signal.

It should be noted that the amplifier **301** is not a common one. It is a zero-peaking amplifier, whose gain curve is shown in FIG. 4A. Referring to FIG. 4A, the gain **401** of the amplifier **301** increases drastically in a high frequency band **402**, and achieves the maximum gain at 2.5 GHz, which is the data transmission rate of the data signal  $V_{in}$ . This is the specific feature of the zero-peaking amplifier. FIG. 4B illustrates the root-mean-square (rms) value of an output voltage  $V_{peak1}$  of the peak detector **303**. Here the amplified data signal  $V_{o1}$  is a differential signal and  $V_{o1+}$  and  $V_{o1-}$  are the different component signals of  $V_{o1}$ . In a conventional circuit, when  $V_{in}$  changes status,  $V_{o1}$  changes status with  $V_{in}$  and a decrease as described by **412** occurs, which may cause misjudgement of the comparator. The enhanced gain of the amplifier **301** in the high frequency band **402** boosts  $V_{peak1}$  as described by **411** for compensating a voltage droop as described by **412**, thus preventing the comparator **304** from misjudging the quality of the data signal  $V_{in}$ .

FIG. 5 is an amplifier circuit diagram of FIG. 3. According to an embodiment of the present invention, the NRZ data signal  $V_{in}$  and the reference voltage  $V_{ref}$  are differential signals. The data signal is constituted of a positive signal  $V_{in+}$  and a negative signal  $V_{in-}$ , and the reference signal is constituted of a positive signal  $V_{ref+}$  and a negative signal  $V_{ref-}$ . Similarly, the amplified data signals  $V_{o1}$  and reference voltage  $V_{o2}$  are also differential signals, each of which being constituted of a positive signal and a negative signal thereof respectively.

The amplifier **301** includes transistors **Q1** to **Q3**, capacitors **C1** and **C2**, resistors **R1** and **R2**, and variable resistors **VR1** and **VR2**. The resistor **R1** is coupled to a voltage source  $V_{DD1}$ . The transistor **Q1** is coupled to the resistor **R1**. The variable resistor **VR1** is coupled to the transistor **Q1**. The resistor **R2** is coupled to the voltage source  $V_{DD1}$ . The transistor **Q2** is coupled to the resistor **R2**. The variable resistor **VR2** is coupled to the transistor **Q2**. The transistor **Q3** includes an end coupled to the variable resistors **VR1** and **VR2**, and another end coupled to a ground **GND**. The transistor **Q1** has a gate receiving the positive data signal  $V_{in+}$ , and the transistor **Q2** has a gate receiving the reverse data signal  $V_{in-}$ . The transistor **Q1** has a drain outputting an amplified reverse data signal  $V_{o1-}$ , and the transistor **Q2** has a drain outputting an amplified positive data signal  $V_{o1+}$ .

The amplifier **302** includes transistors **Q4** to **Q6**, resistors **R3** and **R4**, and variable resistors **VR3** and **VR4**. The resistor **R3** is coupled to the voltage source  $V_{DD1}$ . The transistor **Q4** is coupled to the resistor **R3**. The variable resistor **VR3** is coupled to the transistor **Q4**. The resistor **R4** is coupled to the voltage source  $V_{DD1}$ . The transistor **Q5** is coupled to the resistor **R4**. The variable resistor **VR4** is coupled to the transistor **Q5**. The transistor **Q6** includes an end coupled to the variable resistors **VR3** and **VR4**, and another end coupled to the ground **GND**. The transistor **Q4** has a gate receiving the positive data signal  $V_{ref+}$ , and the transistor **Q5** has a gate receiving the reverse data signal  $V_{ref-}$ . The transistor **Q4** has a drain outputting an amplified reverse data signal  $V_{o2-}$ , and the transistor **Q5** has a drain outputting an amplified positive data signal  $V_{o2+}$ .

The transistor **Q3** of the amplifier **301** and the transistor **Q6** of the amplifier **302** belong to a same current mirror structure which is not completely illustrated in its entirety in FIG. 5.

Direct current data signals  $V_{in}$  cannot pass the capacitors **C1** and **C2**. In this manner, circuits of respectively amplifiers **301** and **302** are identical with respect to direct current data signals  $V_{in}$ . The data signal  $V_{in}$  and the reference voltage  $V_{ref}$  pass equivalent paths, during which there is no level added thereto. As such, the comparison between  $V_{in}$  and  $V_{ref}$  is accurate. With respect to alternating current data signals, the capacitors **C1** and **C2** are conductive, so that the amplifier **301** takes advantage of zero-peaking so as to solve the problem of output voltage droop of the peak detector. As such, the comparison between  $V_{in}$  and  $V_{ref}$  is still accurate. It should be noted that the zero-peaking amplifier can be realized in many approaches, and the one as shown in FIG. 5 is only exemplified for illustration. However, any of the others applied according to the present invention should be construed within the scope of the present invention.

FIG. 6 is a circuit diagram of the peak detector **303**. The peak detector **303** includes two identical sections, left and right. The left section is used for processing the amplified data signal  $V_{o1}$ , and the right section is used for processing the amplified reference voltage  $V_{o2}$ .

The left section of the peak detector **303** includes transistors **Q7**, **Q8**, a current source **I1**, and a capacitor **C3**. The transistor **Q7** is coupled to a voltage source  $V_{DD2}$ . The transistor **Q8** is coupled to the voltage source  $V_{DD2}$  and the transistor **Q7**. The current source **I1** has an end coupled to a common source electrode of the transistors **Q7** and **Q8**, and another end coupled to the ground **GND**. The capacitor **C3** has an end coupled to the common source electrode of the transistors **Q7** and **Q8**, and another end coupled to the ground **GND**. The capacitor **C3** and the current source **I1** are connected in parallel. A gate of the transistor **Q7** receives the amplified positive data signal  $V_{o1+}$ , and a gate of the transistor **Q8** receives the amplified reverse data signal  $V_{o1-}$ . The peak detector **303** relies on the capacitor **C3** to maintain the maximum value of the amplified data signal  $V_{o1}$ . A maintained data signal  $V_{peak1}$  is outputted from a connection node of the common source electrode of the transistors **Q7** and **Q8** and the capacitor **C3**.

The right section of the peak detector **303** includes transistors **Q9**, **Q10**, a current source **I2**, and a capacitor **C4**. The transistor **Q9** is coupled to the voltage source  $V_{DD2}$ . The transistor **Q10** is coupled to the voltage source  $V_{DD2}$  and the transistor **Q9**. The current source **I2** has an end coupled to a common source electrode of the transistors **Q9** and **Q10**, and another end coupled to the ground **GND**. The capacitor **C4** has an end coupled to the common source electrode of the transistors **Q9** and **Q10**, and another end coupled to the ground **GND**. The capacitor **C4** and the current source **I2** are connected in parallel. A gate of the transistor **Q9** receives the amplified positive reference voltage  $V_{o2+}$ , and a gate of the transistor **Q10** receives the amplified reverse reference voltage  $V_{o2-}$ . The peak detector **303** relies on the capacitor **C4** to maintain the maximum value of the amplified reference voltage  $V_{o2}$ . A maintained reference voltage  $V_{peak2}$  is outputted from a connection node of the common source electrode of the transistors **Q9** and **Q10** and the capacitor **C4**.

The peak detector **303** can lower the frequency of the data signal  $V_{in}$ , so as to enable the comparator **304** to compare data  $V_{in}$  which are of a high frequency, thus increasing the operable frequency bandwidth. Distinct from the conventional single-end design as shown in FIG. 2, the peak detector **303** according to the present invention is designed to be a differential full wave rectifier with pairs of transistors. This peak

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full wave rectifier design is featured in that it is functionally operable to compare both of the positive semi-cycle and the negative semi-cycle of the differential signal when the data signal  $V_{in}$  changes status, so as to solve the problem of voltage droop caused by conventional peak detectors.

According to an aspect of the present invention, all of the transistors employed are metal oxide semiconductor field effect transistors (MOSFET). However, this is not to exclude other kinds of transistors to be used in the present invention.

In summary, a path of a direct current data signal and a path of the reference voltage are completely symmetrical configured. As such, the present invention is accurate in comparing direct current data signals. In another hand, the zero-peaking amplifier generates relatively large gain for alternating current data signals for compensating voltage droop caused by the peak detector. The peak detector according to the present invention is designed with a full wave rectifier, so as to be capable of comparing both of the positive semi-cycle and the negative semi-cycle of the differential signal. Therefore, the present invention would not cause misjudgement when comparing alternating current data signals.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

What is claimed is:

1. A signal comparison circuit, comprising:
  - a first amplifier, receiving and amplifying a data signal, wherein the first amplifier is a zero-peaking amplifier;
  - a second amplifier, receiving and amplifying a reference voltage, wherein the data signal passes through a first path in the first amplifier and the reference voltage passes through a second path in the second amplifier, the first path and the second path are equivalent;
  - a peak detector, coupled to the first amplifier and the second amplifier, detecting and maintaining maximum values of respectively the amplified data signal and the amplified reference voltage and outputting the maintained data signal and the maintained reference voltage; and
  - a comparator, coupled to the peak detector for comparing the maintained data signal with the maintained reference voltage, and outputting a comparison result therefrom, wherein a maximum gain of the first amplifier for the data signal is located according to a data transmission rate of the data signal and the first amplifier generates the maximum gain for compensating output voltage droop of the peak detector caused by internal current leakage of the peak detector.
2. The signal comparison circuit according to claim 1, wherein the data signal and the reference voltage are differential signals.
3. The signal comparison circuit according to claim 2, wherein the first amplifier comprises:
  - a first transistor, coupled to a first voltage source;
  - a second transistor, coupled to the first voltage source;
  - a third transistor, coupled between the first transistor, the second transistor, and a ground terminal;
  - a first capacitor, coupled between the first transistor, the third transistor, and the ground terminal; and
  - a second capacitor, coupled between the second transistor, the third transistor, and the ground terminal; wherein a gate of the first transistor receives a positive signal of the data signal;

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a gate of the second transistor receives a negative signal of the data signal;

a drain of the first transistor outputs a negative signal of the amplified data signal;

a drain of the second transistor outputs a positive signal of the amplified data signal;

the first and the second capacitors block direct current signals and conduct alternating current signal so that the first amplifier has zero-peaking characteristics and compensates the output voltage droop of the peak detector.

4. The signal comparison circuit according to claim 3, wherein a first end of the first capacitor is coupled between the first transistor and the third transistor; a second end of the first capacitor is coupled to the ground terminal; a first end of the second capacitor is coupled between the second transistor and the third transistor; and a second end of the second capacitor is coupled to the ground terminal.

5. The signal comparison circuit according to claim 3, wherein the first amplifier further comprises:

a first resistor, coupled between the first voltage source and the first transistor; and

a second resistor, coupled between the first voltage source and the second transistor.

6. The signal comparison circuit according to claim 3, wherein the first amplifier further comprises:

a first variable resistor, coupled between the first transistor and the third transistor; and

a second variable resistor, coupled between the second transistor and the third transistor.

7. The signal comparison circuit according to claim 2, wherein the second amplifier comprises:

a fourth transistor, coupled to a first voltage source;

a fifth transistor, coupled to the first voltage source; and

a sixth transistor, coupled between the fourth transistor, the fifth transistor, and a ground terminal; wherein

a gate of the fourth transistor receives a positive signal of the reference voltage;

a gate of the fifth transistor receives a negative signal of the reference voltage;

a drain of the fourth transistor outputs a negative signal of the amplified reference voltage; and

a drain of the fifth transistor outputs a positive signal of the amplified reference voltage.

8. The signal comparison circuit according to claim 7, wherein the second amplifier further comprises:

a third resistor, coupled between the first voltage source and the fourth transistor; and

a fourth transistor, coupled between the first voltage source and the fifth transistor.

9. The signal comparison circuit according to claim 7, wherein the second amplifier further comprises:

a third variable resistor, coupled between the fourth transistor and the sixth transistor; and

a fourth variable resistor, coupled between the fifth transistor and the sixth transistor.

10. The signal comparison circuit according to claim 2, wherein the peak detector employs a capacitor for maintaining the maximum values of the amplified data signal and the amplified reference voltage.

11. The signal comparison circuit according to claim 10, wherein the peak detector comprises:

a seventh transistor, coupled to a second voltage source;

an eighth transistor, coupled to the second voltage source and the seventh transistor;

a first current source, coupled between the seventh transistor, the eighth transistor, and a ground terminal; and

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a third capacitor, coupled between the seventh transistor, the eighth transistor, and the ground terminal, and connected in parallel with the first current source; wherein a gate of the seventh transistor receives a positive signal of the amplified data signal;

a gate of the eighth transistor receives a negative signal of the amplified data signal;

a common source of the seventh transistor and the eighth transistor outputs the maintained data signal.

**12.** The signal comparison circuit according to claim **10**, wherein the peak detector comprises:

a ninth transistor, coupled to a second voltage source;

a tenth transistor, coupled to the second voltage source and the ninth transistor;

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a second current source, coupled between the ninth transistor, the tenth transistor and a ground terminal; and a fourth capacitor, coupled between the ninth transistor, the tenth transistor, and the ground terminal, and connected in parallel with the second current source; wherein

a gate of the ninth transistor receives a positive signal of the amplified reference voltage;

a gate of the tenth transistor receives a negative signal of the amplified reference voltage;

the common source of the ninth transistor and the tenth transistor outputs the maintained reference voltage.

**13.** The signal comparison circuit according to claim **1**, wherein the data signal is a not-return-to-zero (NRZ) data signal.

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